Development and Applications of Technology for Sensing Zooplankton

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LONG-TERM GOALS

The long-term goal of our research is to improve our ability to observe the ocean's plants, animals and their physical and chemical environment at the critical scales which control how they live, reproduce and die.

OBJECTIVES

Our work currently focuses on two distinct research thrusts. The first involves looking for thin layer and other critical scale phenomena in several littoral locations with different physical and biological environments. We are conducting a series of low cost, "quick-look" surveys at several coastal sites. The surveys employ a TAPS-6 to monitor vertical zooplankton distributions, abundances and size spectra of zooplankton and micronekton. Data are collected at one minute intervals with a depth resolution of 12.5 cm for a few weeks at each location. This work addresses questions of the frequency of occurrence of thin layers in geographically separated, oceanographically diverse littoral environments. We also hope to add information to a growing body of evidence that suggests a better knowledge of these phenomena is important for understanding littoral ecosystems. Concentrations of up to 78% of the water column's zooplankton biomass have been observed in thin layer structures, which are sometimes less than a meter thick (Holliday, 1998).

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Our second research thrust involves development of measurement technology and models to support the use of multi-static, multi-frequency scattering in studies of small zooplankters and micronekton. Understanding 3-D scattering across a wide frequency spectrum, both theoretically and by direct measurement, could lead to extraction of not only size, but also shape and physical properties of plankters in aquatic environments. This work examines concepts in basic scattering measurement and theory that go well beyond their application in assessment of zooplankton for ecological purposes.

WORK COMPLETED

We have prepared one copy of the instrumentation needed for deployment in support of our "quick-look" surveys. The system consists of a TAPS-6 in its echo ranging mode, two-way telemetry and a thermistor string. With the cooperation of the Naval Beach Group 1, the system has been tested at a shallow-water coastal site near LCAC base at Camp Pendleton, a few miles north of Oceanside, CA.

In anticipation of the data we anticipate from shallow coastal sites, we have expanded our multi-frequency inverse code to include a capability to use Stanton's simplified Distorted-Wave Born Approximation (DWBA) method in our inverse processing (Stanton *et al* 1993; Chu *et al* 1993; Stanton *et al* 1998). We have used McGehee's adaptation of Stanton's approach (McGehee, *et al* 1998) for modeling scattering from a wide variety of zooplankton and micronekton. The result is that we can now make use of *a priori* information when one or more species in an assemblage is known to have contributed to the scattering in a particular data set, given that we have information on the animal's shape.

We have made our first detailed multi-static, multi-frequency measurements of scattering. In order to test our measurement process, and the software we use to examine the data, we used a series of small precision objects, cast from an acoustically penetrable material (RTV) with well known, stable physical properties. The measured data spans acoustical frequencies from about 200 kHz to about 2 MHz. High quality measurements of the scattered broadband signals were made at one degree angles from about 10 degrees off the forward scattering direction to about 10 degrees from backscattering direction. The temporal domain theoretical scattering from several of these targets have been modeled and the results compare very well with the measured data.

RESULTS

In August 2001 we deployed a TAPS about 2 nm off Red Beach at Camp Pendleton, north of Oceanside, CA. Our main purpose was to conduct a simple test of our mooring procedures for deploying the system from a small boat, to make sure some new changes in the data acquisition software worked, and to test the telemetry we will be using at several other coastal sites this fall and next spring. Thin layer structures were observed during each of the 8 days of this deployment. At times, several thin layers were present at different depths during the same period. A seven-hour record from August 12 (Figure 1) reveals rapid vertical modulations of this zooplankton response to the local environment.

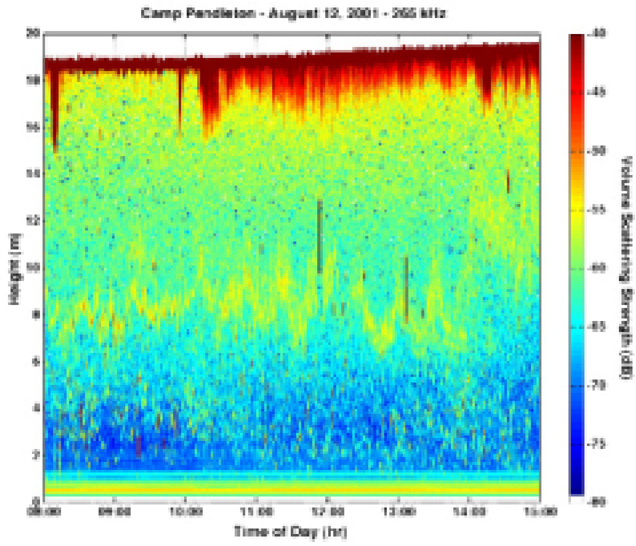

Figure 1: Rapid vertical modulation of a thin layer observed in August 2001 at a site located about 2 nm west of Red Beach at Camp Pendleton, near Oceanside, CA. Volume scattering strength data were collected at one minute intervals with a vertical resolution of 12.5 cm. The acoustic frequency for this data set was 265 kHz. The vertical excursions of this layer were five to ten times the average layer thickness with periods of less than an hour.

The long, exposed, linear coast at Camp Pendleton is subject to both intense internal wave activity and to wind- and tidally-driven advective processes. Sharp changes in layer depth of more than 5 m within less than a half an hour were not uncommon at this site (e.g., 14:00 hrs, Figure 1). During the nighttime hours zooplankton, fish and micronekton appeared to migrate into the water column from daytime locations both near the surface and near, or in, the bottom. During most of the nights, the scattering strengths of the layers increased by roughly an order of magnitude, implying an increased concentration of predators in the layer structures during the dark over those present during the daylight hours. Plumes of high local scattering extended into the water column two to three meters during times when onshore winds exceeded about 5 m/s and in this instance were likely caused by the mixing of small bubbles from breaking waves into the water column.

Based on the results of the tests we conducted off Camp Pendleton, a second “quick-look” TAPS-based measurement system is nearing completion. This will allow us to occupy sites at different geographic locations at the same time and will also serve as a backup in case one system is damaged or lost. Plans have been made to occupy at least two additional shallow-water sites during the fall of 2001. We also plan to occupy several other coastal sites during 2002. At selected sites, other ONR-sponsored investigators (e.g., Percy Donaghay, URI and Margaret Dekshenieks, UC Santa Cruz) will join us with a limited array of instrumentation for measuring the optical and physical environment.

The deliberate step-by-step process we have taken to developing multi-static, multi-frequency technology revealed several unexpected issues with the required precision of target centering. As these issues have now been resolved for relatively simple objects, we are now preparing to address scattering from more complex target shapes.

IMPACT/APPLICATION

Observation of aquatic animals in their natural environments continues to pose a major challenge in both biological oceanography and limnology. Critical processes in feeding, reproduction, growth and predation occur at scales from fractions of millimeters up to scales that match the ambits of individuals. Our work is focused on the invention and development of new, high-resolution methods and technology for observing zooplankton and micronekton *in situ*.

The dynamic changes in the layer structures observed off Camp Pendleton (Figure 1) reinforces our impression that reliably sampling these sub-meter scale structures to collect their physical and biological constituents is a major challenge. There is an increasing body of evidence suggesting that these structures are ecologically important and, as a relatively new discovery, the mechanisms involved in their formation and utilization by different trophic assemblages are still largely unknown. Successfully addressing the problems associated with directed sampling of these structures (physics, chemistry, and biology through at least the micronekton) must be successfully addressed before we can fully understand the processes that lead to their formation, persistence and dissolution.

Phytoplankton and zooplankton impact marine optics and underwater acoustics through both scattering and absorption. As many sensors used by naval forces rely on either optical or acoustical energy, the distribution of marine life potentially impacts current and future naval systems used in shallow water, where mine detection and ASW operations must be conducted prior to engaging in expeditionary warfare.

TRANSITIONS

We continue to support several other ONR principal investigators (e.g., Donaghay, Dekshenieks, Jumars) in the applications of our latest hardware and software developments to their own science programs. Similar low-level consulting activities are also ongoing with some NOAA projects (Napp, Roman, Boicourt). A typical low level support activity of this kind was a recent full system calibration of a commerical ADCP for Mark Benfield (LSU). Quantitative data collected as a result of this activity was presented at the 141st Acoustical Society of America meeting in Chicago (Benfield, *et al* 2001).

RELATED PROJECTS

Technology developed under this project has been extensively used in the ONR Thin Layers program, the ONR SAX-99 program and in two programs at the University of Maryland's Horn Point Laboratory (with Mike Roman and Bill Boicourt). One of those programs, both of which dealt with ecosystems research in the Chesapeake Bay, was sponsored by NSF and the other by NOAA.

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PUBLICATIONS

Preparation of the following publications depended wholly, or in part, on funding received under this project.

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